CATTAIL DECLINE AT FARMINGTON BAY WATERFOWL MANAGEMENT AREA[1]

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Abstract.— For the last seven years, 1969 to 1976, a steady decline of cattails (*Typha latifolia* L.) has been observed at Farmington Bay Waterfowl Management Area, Davis County, Utah. Several parameters of Farmington Bay's environment that could cause or enhance a decline of the marshland vegetation were studied. These parameters included temperature, pH, phenols, oil and grease, heavy metals, fungus pathogens, and salt water intrusion from the Great Salt Lake. Elevated soluble salt concentrations were found to be responsible for the decline. Cattails are weakened or killed when they are exposed to soluble salt concentrations greater than 5.0 gm/liter, and there is a significant (1 percent level) negative correlation (–0.68) between soluble salt concentration and cattail height. Symptoms of elevated salt concentrations include stunted growth, leaf tip necrosis (burning), and occasional browning of an entire cattail clone. Furthermore, those salt concentrations that cause physiological stress in cattails also facilitate the growth of a decomposition fungus, *Chaetophoma confluens*. This fungus causes a rot consisting of irregularly scattered lesions on the surface of the rhizomes and was consistently isolated from rhizomes of declining plants.

For the last seven years, 1969 to 1976, a steady decline of cattails has been observed at Farmington Bay Waterfowl Management Area, Davis County, Utah. The management area is 4,205 feet above sea level, located on the east shore of the Great Salt Lake, 15 miles north of Salt Lake City. The primary water source is the Jordan River. Water flows northwesterly, and Farmington Bay flows directly into the Great Salt Lake.

At Farmington Bay, cattails in many areas were less than 1 m high, as compared to healthy cattails that frequently attained heights of 2 m. During the summer, cattails appeared to grow normally until July; growth then ceased. Yellowing and necrosis followed rapidly. Older parts of the cattail clones died first, with the younger shoots gradually following the same pattern. Inspection of the rhizomes revealed the presence of mahogany-colored cankers, or lesions, scattered irregularly over the surface. In some cases the lesions had extended deep into the tissues, and some rhizomes had completely rotted away.

These symptoms are characteristic of those caused by soil fungus pathogens, and it was suspected that the lesions might be the result of such a fungus and, in turn, that the lesions might cause the plant's decline. A fungus might act either as a primary pathogen or a weak, secondary pathogen, affecting tissues subjected first to some other stress. If this were the case, it would be necessary to establish what stresses might be involved and to define their relative contribution to the cattail decline.

The objectives of this study were to: 1) determine the cause or causes of the cattail decline; 2) evaluate the seriousness of the situation; and 3) provide information so that corrective or control measures could be developed to protect existing marshland vegetation and reestablish vegetation that had been destroyed.

A fourth objective was to better understand the marsh ecosystem. In this system, decomposition is an ecological factor that may be important in affecting marsh plant interactions. The declining cattails offered an opportunity to study how fresh-water marshlands might undergo decomposition and change.

The broad-leaved cattail (*Typha latifolia* L.) is common to North American marshlands and dominant in Utah's waterfowl management areas. Other common marsh

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plants are alkali bulrush (*Scirpus paludosus* A. Nels.), hardstem bulrush (*Scirpus acutus* Muhl.), salt grass (*Distichlis stricta* Torr. Rydb.), and salicornia (*Salicornia rubra* A. Nels. and *Salicornia pacifica* Standl.).

Important as a successional species, the cattail is a plant that traps sediment and nutrients, allowing the subsequent establishment of bulrushes. Bulrushes, the climax species of the marsh, provide abundant waterfowl food. Cattails, on the other hand, have little value as waterfowl food, and, when it is dominant in waterfowl management areas, the cattail is considered a nuisance because its dense stands make it useless as nesting habitat or escape cover. Cattail rhizomes are palatable to humans, muskrats, and geese; the plants themselves are used by waterfowl for nesting and escape cover when their growth has been controlled.

The most significant publication on the subject of Utah marshlands contains the results of 25 years of experimental work at Ogden Bay Refuge, 12 miles west of Ogden, Utah, near the east shore of the Great Salt Lake (Nelson 1954). The purpose of the study was to determine how marshland could be developed and waterfowl populations increased; records were kept to ascertain how plant community changes influenced animal populations. Several of the conclusions were pertinent to the present study at Farmington Bay.

Major factors limiting plant growth and waterfowl use at Ogden Bay included water supply, seasonal water fluctuations, fluctuations of the Great Salt Lake, and overgrazing. Salt tolerance differed among plant species. Of the emergent species, alkali bulrush was the most tolerant; cattail was second. All of the marsh plants were able to tolerate soil salinities exceeding the salinity ranges for agricultural crops. As plant cover was increased, waterfowl populations increased because new nesting areas were created and abundant food was made available.

After vegetation had been developed on the Ogden Bay Refuge, it became evident that cattails, especially in the less saline areas of the marsh, could effectively outcompete other plants. Dense stands, useless for waterfowl nesting, were established. In 1947, cattail control studies were initiated by the Utah State Department of Fish and Game (Nelson and Dietz 1966). The control methods used to experimentally eliminate cattails included cutting, crushing, and mowing; chemical sprays; explosives; fire; and drought. It was concluded that by adjusting the water levels cattail overgrowth could be controlled; when mud flats were not covered with water during the growing season, large-scale cattail invasions occurred.

At Fish Springs, a salt marsh west of Salt Lake City, *Typha angustifolia* (narrow-leaved cattail) does not form large communities (Bolen 1964). Bolen noted that *Scirpus acutus* and *Typha latifolia*, common species of Utah's fresh-water marshes, did not occur at Fish Springs. He concluded from his data that while it was probable that salinity limited the development of these species, water depth or some other factor was probably responsible for their absence at Fish Springs.

In contrast to the Fish Springs study, data on physical and chemical soil constituents at Bear River Bird Refuge indicated that soluble salts affected the yields of aquatic plants. Areas low in soluble salts were more productive than areas high in soluble salts (Jensen 1940). It was determined that high salinity, in addition to affecting vegetative growth, interferes with seed germination and seed production of Utah marsh plants (Kaushik 1963).

Literature published on other localities stresses the importance of soil salinity in interactions between marsh plants (Haller 1974). Salinity is considered to be a primary factor in determining plant distributions in Louisiana marshes; cattails are limited to fresh-water areas of less than 0.5 percent salt (Penfound and Hathaway 1938). Water levels, in addition to salinity, are also thought to determine plant distribution (Bourn and Cottam 1939).

Cattail populations growing in disturbed salt flats have salt tolerances characteristic of each species. A concentration of 1 percent sodium chloride in hydroponic tanks caused stunting, drying, and leaf curl in *Typha latifolia*. *Typha angustifolia* was able to withstand 2 percent sodium chloride concentrations. A hybrid intermediate, *Typha glauca*, had an intermediate salt tolerance (McMillan 1959). Since many terrestrial plants also differ widely in their salt tolerance (Levitt 1972), an effort was made to determine the relationships between cattail decline and salinity at Farmington Bay.

Methods

Five different features of the problem were studied: 1) the isolation of a possible fungus pathogen; 2) the investigation of environmental stress conditions; 3) the evaluation of marshland by aerial photography; 4) laboratory experimentation on the effects of salinity on cattail growth; and 5) laboratory experimentation on the effects of salinity on the growth of an isolated fungus.

1. Isolation of the fungus: Diseased cattails were collected, and plant tissue was cut from necrotic lesions with a sterile scalpel. The infected tissue was surface sterilized and placed on Difco-Bacto Agar with nitrogen or Difco potato dextrose agar. Plant tissue was surface sterilized with a 10 percent aqueous solution of Purex bleach.

Pure cultures were obtained by transferring the developing fungus mycelium onto fresh agar. Cultures were allowed to grow at room temperature. Slant test tube cultures provided a method of storage, and they were refrigerated until used. The fungi were identified. Fungus mycelium was mounted on temporary slides with a drop of water for most identifications. To aid in the identification of one species (*Chaetophoma confluens*), fixing, sectioning, and staining were used. Tissue was fixed in formalin-aceto-alcohol and embedded in paraffin. Sections, 15 microns thick, were stained with safranin 0 according to the methods described by Johansen (1940).

2. Environmental parameters: Studies were conducted to determine the environment's contribution to the vegetation decline. This included measuring salinity, pH, biological oxygen demand (BOD), dissolved oxygen (DO), and temperature. Samples of soil and water were taken weekly during the months of May through September, 1974. All routine sampling was done at the four sampling sites shown on Figure 1. Cattails appear to be healthy at Site 1 and Site 3. Cattails are in a state of decline at Site 2; Site 4 represents the outlet of Farmington Bay and has no cattails.

Conductivity of both soil extracts and water samples was measured in the laboratory at 25 C with a conductivity bridge (Richards 1954). Then pH was measured to the nearest tenth of a pH unit with a Beckman pH meter. BOD samples were taken once a month and analyzed by the Utah State Division of Health. Water samples for dissolved oxygen were measured weekly in the field according to the azide modification; DO was measured in milligrams per liter and expressed relative to 100 percent saturated water (American Public Health Association 1971). In addition, samples were chemically analyzed monthly by the Utah State Division of Health to determine which industrial pollutants were present. Air and water temperature were measured in the field with a centigrade thermometer. The data obtained were used to calculate the percent of dissolved oxygen in the water. Weather conditions for the summer were recorded and compared with previous summer conditions.

3. Mapping of vegetation: Aerial photographs and moving films of Farmington Bay and the surrounding area were taken. The Ogden Bay Waterfowl Management Area, the Bear River Bird Refuge, and Red Butte Canyon were also examined for indications of vegetation decline in order to determine if the decline was in some way uniquely associated with Farmington Bay. A vegetation map of Farmington Bay was made so that the affected area could be properly illustrated and the extent of damage could be determined. A U-2 infrared aerial photograph (scale 1:120,000) was projected onto a United States Geological Survey Map (Farmington Quadrangle, scale 1:24,000) with a Bausch and Lomb Zoom Transfer Scope. Areas covered by marsh vegetation were traced onto the geological survey map. The U-2 infrared photograph, obtained from the Geography Department at the University of Utah, was taken 14 September 1972 by a high-flying aircraft at about

50,000 feet. Standard infrared film was used in a high-resolution camera. Healthy vegetation is bright red, vegetation under stress is salmon colored, and dead vegetation is white. A compensating polar planimeter was used to determine the area covered by healthy marsh vegetation and the extent of diseased vegetation.

Color aerial photography for assessing the quality of marshlands has just recently come into use. Further information on the methods used in aerial mapping of marshlands can be obtained from Seher and Tueller (1973); the source also explains how infrared photographs should be interpreted. In addition, a bibliography on the use of aerial photography (Anson 1975) has been compiled that provides more detailed information.

4. Laboratory experiments determining effects of salinity on cattail growth: Cattails were grown from seeds gathered at Farm-

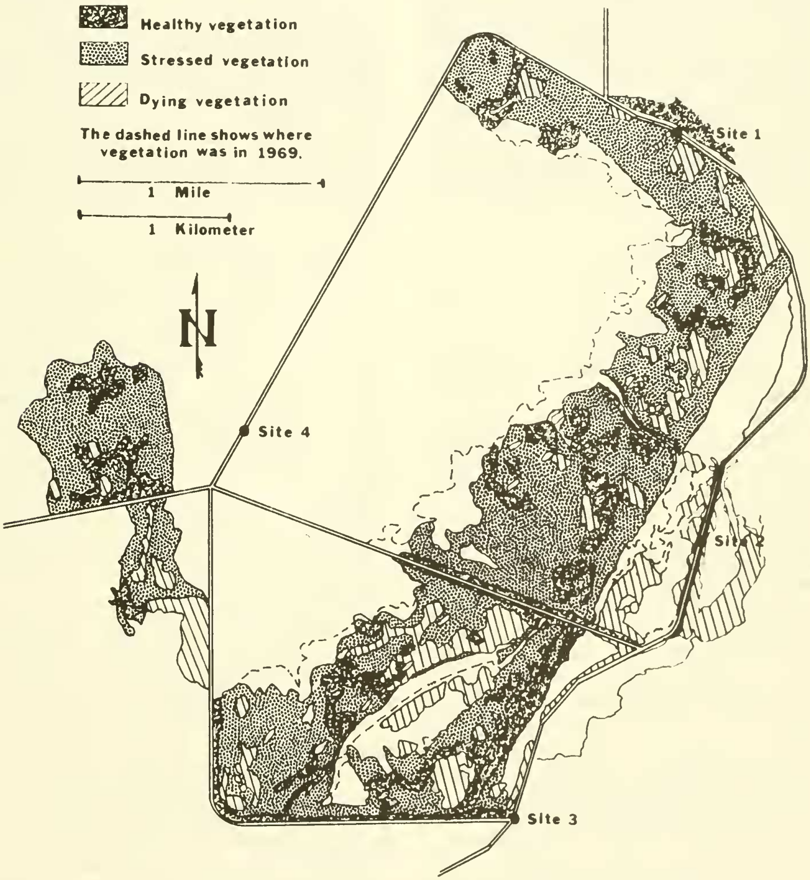

Fig. 1. Farmington Bay Waterfowl Management Area.

ington Bay. Seedlings were transferred to six hydroponic tanks when they were about six inches high; the tanks contained a four-salt nutrient solution made according to the methods described by Arnon and Hoagland (1940). Nutrients were replaced monthly during the experiment. Each of six hydroponic tanks contained 10 individual plants. Two tanks served as the control; the other four tanks were used to determine the effects of different salt concentrations on the cattails. After the seedlings had acclimatized and had shown vigorous growth, sodium chloride was added in small amounts (0.01 Mole per day) over a period of 30 days. This was done to determine a realistic salt tolerance for the cattails without putting them under undue stress. Shoot growth of each plant was measured every two days. The final concentrations at the end of the period of additions were two tanks with 0.0 M sodium chloride, two tanks with 0.1 M sodium chloride, and two tanks with 0.3 M sodium chloride. The cattails in one tank of each salt concentration were inoculated with *Chaetophoma confluens*, the fungus that was most often isolated from the lesions on the cattail rhizomes. Inoculation was performed by injecting a fungus-water suspension into the host with a hypodermic syringe.

Cattail rhizomes were observed throughout the experiment for the development of lesions and other symptoms of stress. When the experiment was terminated, a wet weight for shoots and rhizomes of each plant was obtained. Tissue from all experimental plants was cultured for isolation of the fungi that were present.

5. Effect of salinity on the fungus, *Chaetophoma confluens*: *Chaetophoma confluens* was grown on potato dextrose agar, to which sodium chloride had been added. The following sodium chloride concentrations were prepared: 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, and 0.8 M. Cultures of each salt concentration were inoculated with 0.5 cmsquares of mycelium and were allowed to grow for two weeks in an oven held at 30 C. The area covered by fungus mycelium was determined by tracing the area onto paper, cutting, and weighing. The average growth area at each salt concentration was graphed.

Results

Three fungus species were isolated from diseased cattails that had been collected at Farmington Bay. *Fusarium tricinctum* was isolated in 12 (16.2 percent of the isolated fungi) out of 74 fungus isolations. *Botrytis cinerea* was isolated 14 times (18.9 percent). Both of these fungi are saprophytic on decaying plant material. *F. tricinctum* occurs frequently on moldy corn and grain; *B. cinerea* causes "gray mold" of numerous ornamental and crop plants (Barron 1968). Neither of these fungi has been reported to occur on *Typha*.

Chaetophoma confluens was isolated 48 times (64.9 percent). *Chaetophoma* might be an important decomposition fungus in the marsh. It has been isolated from *Spartina* (cordgrass), a common emergent in salt-water marshes (Barnett 1956).

Another fungus, tentatively identified as a species of *Olpidium*, was discovered when the stained sections of cattail rhizomes were examined; the relationship of this fungus to cattail rhizome rot is unclear. Only a few species of *Olpidium* are parasitic on higher plants. When *Olpidium* infects clover or vetch, it causes distortions of the leaves; in one species of grass, *Agrostis stolonifera*, it causes root hair distortion. *Chytridiomycetes* (the fungus class that includes *Olpidium*) are characterized by the production of motile cells and are typically found in aquatic habitats (Sparrow 1943).

The most probable cause of the vegetation decline was revealed when the results of the water and soil analyses were examined. Figures 2 and 3 show the results of the conductivity measurements. The figures show that the salinity increases dramatically during the summer at Site 2, reaching a maximum during the month of July. This peak coincides with the period during which cattail deaths were first observed during the summer. The salinity peak also came just after the Great Salt Lake reached its high of 4,201.30 feet above sea level in June (United States Geological Survey

1975). The 4,205-foot level is shown along the east side of Farmington Bay on a United States Geological Survey Map of the area; the west side of the management area is approximately 4,200 feet above sea level. Apparently, the management area is at the same elevation as are the Great Salt Lake brines for part of the summer. Chemical analyses of the water at Farmington Bay showed that sodium and chloride ions were present in the greatest amounts at this time. It was concluded that these ions made the largest contribution to the measured conductivity values.

To determine the significance of the relationship between salinity and cattail decline, another experiment was conducted. This experiment consisted of taking water samples every tenth of a mile (0.16 km) along the east side of Farmington Bay and along the dike that runs east and west across the refuge. As water samples were taken, the average height of the cattails was recorded in centimeters. Cattails were measured in a circular area of 10 m in diameter. The point where the water sample was taken served as the center of the circle. Average heights were based on measurements of 20 to 50 cattail plants. Only living cattails were measured. Figure 4 shows a graph of conductivity versus cattail height. There is a moderately high, negative correlation (r = –.68 with 41° of freedom) between conductivity and cattail height. These field data also showed that cattails exhibit disease symptoms when the dissolved salt content exceeds 5.0 gm/1.

The pH of Farmington Bay lies between the normal ranges of river water: 5.0 to 9.0. The data showed that there was no correlation between pH and cattail height.

The BOD at Site 2 progressively increased during the summer, while the BOD at Site 3 and Site 4 increased slightly and

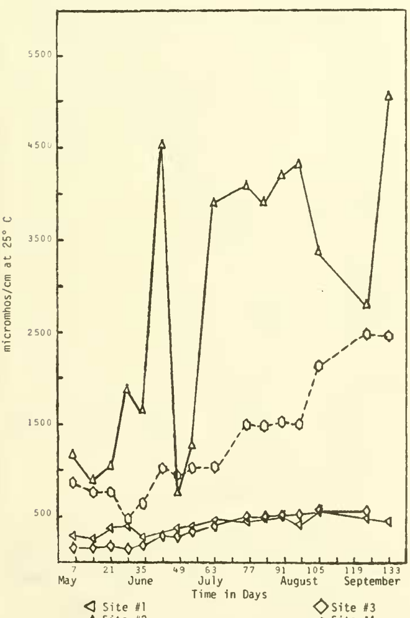

Fig. 2. Conductivity of the water.

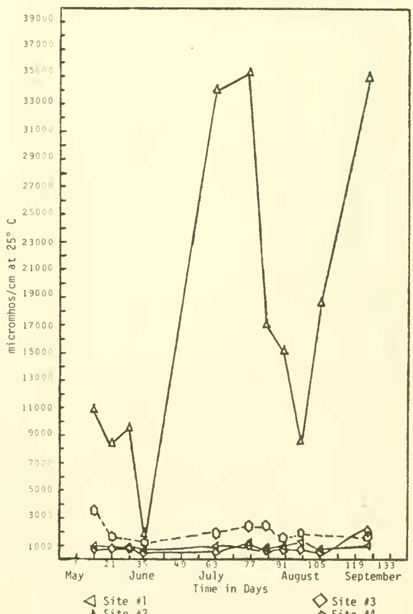

Fig. 3. Conductivity of the soil.

then leveled off (Fig. 5). The large increase indicated that oxidizable organic material was accumulating at Site 2. Results of the DO measurements are shown in Figure 6. Dissolved oxygen at Site 2 got as low as 46 percent saturated. Despite some periods of low DO and high BOD, the dissolved oxygen was high overall during the summer and no detrimental effects were observed that could be related to low oxygen availability.

The results of the chemical analyses showed that the chemical parameters of the water were normal except for the high salinity. Small amounts of phenols, oil, and grease were found in the water, and a discussion of their significance to this study is included in the *Discussion* section of this article.

The effect of sodium chloride on the growth of the fungus, *Chaetophoma confluens*, is shown in Figure 7. The addition of sodium chloride was found to increase growth. Optimum concentration for growth of *Chaetophoma* is 0.30 M sodium chloride. Cattails growing in hydroponic tanks showed symptoms of salt toxicity (leaf burn and wilting) at sodium chloride concentrations of 4.68 gm/l (0.08 M). At sodium chloride concentrations of 17.6 gm/l (0.30 M), growth was completely arrested and rhizomes began to rot. The results correlate well with the results of the field study. Table 1 shows how increased salt concentrations affected the wet weights of shoots and rhizomes.

Attempts to isolate *Chaetophoma* from lesions that developed on cattails following inoculation were unsuccessful. Because of the observed effects of salinity on the cattails, and because *Chaetophoma* was only isolated in two (out of 20) cultures in previous inoculation experiments, it could not be concluded that the fungus was a primary

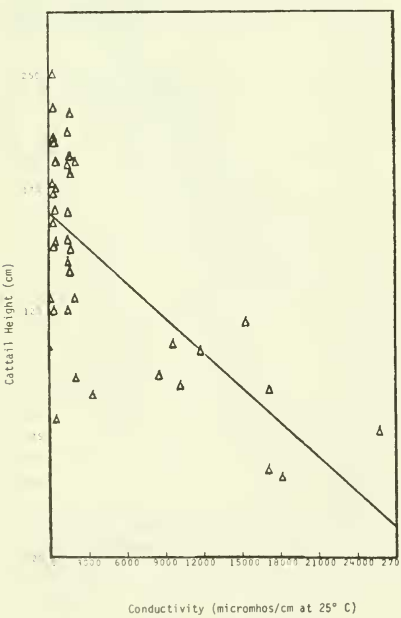

Fig. 4. Conductivity vs. cattail height.

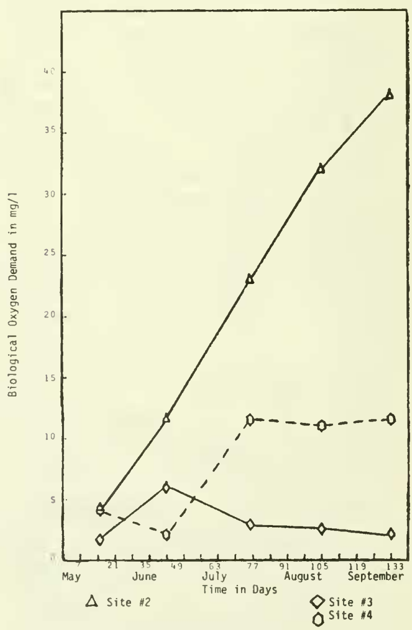

Fig. 5. Biological oxygen demand.

cause of the cattail decline. The combination of the appropriate soluble salt concentration and the fungus appears to be critical in producing the symptoms observed at Farmington Bay. Figure 8 shows that the optimum sodium chloride concentration for *Chaetophoma* growth (0.30 M) corresponds to the salt concentration (0.30 M) that causes cattail death.

TABLE 1. Wet weights of cattail shoots and rhizomes in relation to salinity.[1]

Sodium Chloride Concentration	Rhizome Weight	Shoot Weight	Shoot : Rhizome Ratio
0.0 M	73.0 gm	209.7 gm	2.90 : 1
0.1 M	53.4 gm	58.6 gm	1.10 : 1
0.3 M	26.2 gm	11.1 gm	0.42 : 1

[1]These are the average weights of all the plants that were grown in a given sodium chloride concentration.

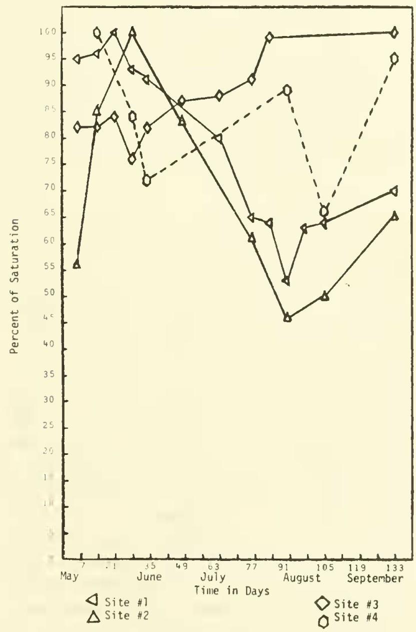

Fig. 6. Dissolved oxygen.

DISCUSSION

At present, the vegetation in Farmington Bay and the neighboring duck clubs appears to be under stress. The stress conditions occur throughout the marsh, leaving very few places unaffected. Healthy vegetation is found only in the higher areas of the marsh and where fresh water is flowing in from the Jordan River.

The portion of Farmington Bay illustrated in Figure 1 has an area of 11.88 square kilometers (2,934 acres). Of this, 4.88 km^2 (1,205 acres) is emergent vegetation. In 1969, Farmington Bay had 5.92 km^2 (1,462 acres) of emergent vegetation; 1.04 km^2 (257 acres) of this vegetation has disappeared, and 1.28 km^2 (316 acres) of vegetation is dying and in the process of disappearing. It is interesting to note that in 1959 there were only 1.40 km^2 (346 acres) of vegetation in the portion of Farmington Bay that is illustrated. At the present time,

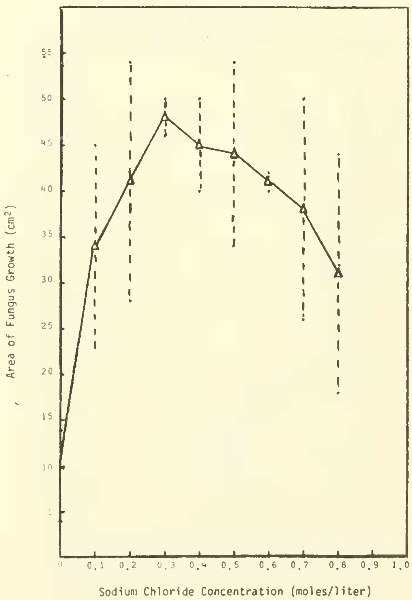

Fig. 7. The effects of sodium chloride on the growth of *Chaetophoma confluens*.

there is more vegetation in Farmington Bay than there was in 1959. The same general pattern of vegetation decline is occurring in the southern portion of Farmington Bay and in the marshland to the south that is not shown in the illustration. The decline appears to be occurring slowly, and it would take several years of similar conditions to eradicate the emergent marsh vegetation.

Several parameters of Farmington Bay's environment could cause or enhance a decline of the marshland vegetation. Among these are adverse temperature ranges, pH, phenols, oil and grease, fungus pathogens, and salt water intrusion from the Great Salt Lake. All of these potential pathogens were examined in this study. The effects that each agent or factor might have on the vegetation, alone or in combination, were considered.

Since no unusual temperature changes have been recorded at Farmington Bay, temperature can be immediately eliminated as the cause of vegetation decline. Marshes in Red Butte Canyon that experience a similar range of air and water temperatures have shown no signs of diseased or dying vegetation. However, the cattails at Farmington Bay are dying during the warmest part of the summer, and it is possible that high temperatures might be enhancing the effects of some other stress to which the cattails have already been subjected.

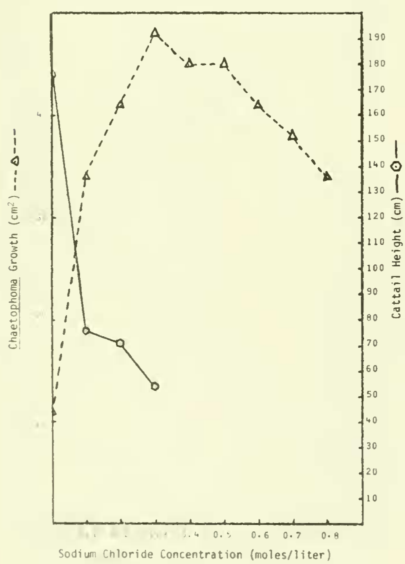

Fig. 8. The effects of sodium chloride on the growth of cattails and *Chaetophoma confluens*.

Soil and water pH greatly affect the availability of plant nutrients. The ideal pH range for most crop plants is from 6.5 to 7.5 (Sprague 1964). Average values above 8.0 or below 5.0 would be necessary to create serious nutrient deficiencies and cause disease. A pH range of 5.0 to 9.0, with an average pH around 8.0, was measured at Farmington Bay. Chlorosis (yellowing of the leaves), which is indicative of many nutrient deficiencies, and other characteristic symptoms that commonly occur in response to the lack of essential elements, were not observed (Treshow 1970). In addition, no statistical correlation could be obtained between pH and cattail growth as determined by height. In other studies conducted on Utah marsh plants, it has been shown that vegetation grows well in the pH ranges that occur at Farmington Bay (Jensen 1940, Nelson 1954, Kaushik 1963). There is little possibility, therefore, that pH is contributing to the vegetation decline.

Analysis of the water at Farmington Bay for possible industrial pollutants revealed the presence of phenols, oil, and grease. Phenolic compounds in water resources are usually a result of pollution from oil refineries. Phenols also result from the breakdown products of herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (Goerlitz and Brown 1972). The oil refineries upstream from Farmington Bay and the herbicide treatment of some grain crops with 2,4-D are the most probable sources of the phenols, oil, and grease in Farmington Bay. Phenol concentrations ranged from none to 0.008 mg/l. These concentrations are extremely dilute when compared to the concentrations of phenolic compounds (such as 2,4-D) that are known to be toxic to broad-leaved dicots (Crafts and Robbins

1962). Since the concentrations of phenols are dilute, there is little possibility that phenols are causing the vegetation decline. However, phenolic compounds might be contributing to the decline by inhibiting the reestablishment of cattail seedlings. McNaughton (1968) has shown that phenols produced by *Typha latifolia* have an autotoxic effect on seed germination and seedling growth. Oil and grease measurements ranged from 0.6 mg/l to 8.0 mg/l. These concentrations are also too dilute to cause any vegetation damage (Goerlitz and Brown 1972).

Study of the total salt content, or salinity, of the soil and water of Farmington Bay revealed that the existing salinities were in a range that is known to be toxic to many plant species (Richards 1954). Field studies showed that cattails are weakened or killed when they are exposed to soluble salt concentrations greater than 5.0 gm/l. Penfound and Hathaway (1938) have also found that *Typha latifolia* plants in Louisiana marshes do not occur where salinities are above 5.0 gm/l. McMillan (1959) found that *T. latifolia* grown in hydroponic tanks could not tolerate 10 gm/l, and Kaushik (1963) found that cattails from Ogden Bay Waterfowl Management Area were killed when subjected to a soluble salt concentration of 0.9 gm/l. Symptoms of the elevated salt concentrations on cattails include stunted growth, leaf tip necrosis (burning), and occasional browning of the entire plant. Furthermore, the salt concentrations that cause a physiological stress to cattails facilitate the growth of a decomposition fungus, *Chaetophoma confluens*. This fungus causes a rot consisting of irregularly scattered lesions on the surface of the rhizomes and was consistently isolated from rhizomes of declining plants. At the beginning of this study, it was thought that the fungus might be a primary cause of the decline. However, elevated soluble salt concentration appears to be the primary cause.

The source of the elevated salt concentration at Farmington Bay is undoubtedly the Great Salt Lake. Salinities in Farmington Bay increase and decrease following the rising and falling of the lake. Salinity measurements of the water entering Farmington Bay from the Jordan River show concentrations of salt between 0.1 gm/l and 0.6 gm/l. These concentrations do not seem to be increasing the salinity of Farmington Bay. The Great Salt Lake, on the other hand, with a salt concentration of 224 gm/l, is a natural source of salt for bordering marshlands because the brines are known to diffuse through and under the dikes around the marshes. The periodic fluctuations of the Great Salt Lake allow for a natural control of the density of cattail stands. This could be either beneficial or detrimental, depending on the frequency and extent of the fluctuations. In order to maintain a desirable stand density, it is suggested that the salinity be monitored and controlled.

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